FLORISTIC COMPOSITION, ABUNDANCE, AND DISTRIBUTION PATTERN OF WOODY PLANTS IN A TROPICAL SAVANNA IN NORTHERN GHANA

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ABSTRACT

The floristic composition, abundance and distribution pattern of woody plants in a tropical savanna in the Sinsabligbini Forest Reserve in northern Ghana was studied using 15 circular vegetation plots of 10 m radius. In total, 2534 individuals of woody plants belonging to 62 species in 19 families were identified. The most species rich and abundant families were Fabacaeae, Combretaceae and Rubiaceae. The abundant woody plants included *Dichrostachys cinerea* (L.) Wright & Arn. (Fabaceae), *Pteleopsis suberosa* Engl. & Diel. (Combretaceae), *Combretum collinum* Fresen. (Combretaceae), *Dalbergia afzeliana* G. Don. (Fabaceae) and *Terminalia mollis* Laws. (Combretaceae). The majority (80.6%) of the woody plant species were found to be highly aggregated in their pattern of distribution while twelve species showed some degree of randomness. The study has shown that the floristic composition and abundance of plants is very variable in different areas of the Guinea Savanna Zone.

Key Words: Woody plants; Guinea savanna; Singsaglebini Forest Reserve; Ghana

RESUMEN

La composición florística, abundancia y patrón de distribución de plantas leñosas en una sabana tropical en la Sinsabligbini Forest Reserve en el norte de Ghana se estudió usando 15 parcelas de vegetación circulares de 10 m de radio. En total se identificaron 2534 individuos de plantas leñosas pertenecientes a 62 especies de 19 familias. Las familias con mayor número de especies y abundantes fueron Fabacaeae, Combretaceae y Rubiaceae. Las plantas leñosas abundantes incluyen *Dichrostachys cinerea* (L.) Wright & Arn. (Fabaceae), *Pteleopsis suberosa* Engl. & Diel. (Combretaceae), *Combretum collinum* Fresen. (Combretaceae), *Dalbergia afzeliana* G. Don. (Fabaceae) y *Terminalia mollis* Laws. (Combretaceae). De la mayoría de las especies leñosas (80.6%) se encontró que estaban altamente agregadas en su patrón de distribución mientras que doce especies mostraron algún grado de azar. El estudio ha mostrado que la composición florística y abundancia de plantas es muy variable en diferentes áreas de la zona de sabana de Guinea.

INTRODUCTION

The most extensive vegetation type in Ghana is the guinea savanna. It is estimated to cover about 60.77% of the total land-mass of Ghana (Anonymous 2002). Previous publications of studies on the guinea savanna vegetation in Ghana include that of Vigne (1936), Taylor (1952), Baker (1962), Lawson et al., (1969), Houssain and Hall (1969), Hopkins (1979), Oteng-Yeboah (1996) and recently Asase and Oteng-Yeboah (2007). Other studies have examined the effect of fire on the savanna (Ramsay & Rose Innes 1963; Brookman-Amissah et al. 1980). Despite these contributions, few studies have documented the diversity and abundance of species of plants found in different areas in the savanna zone of Ghana. This current documentation is of management importance as it contributes to a better understanding of the need to conserve and sustainably utilize plant diversity.

The Sinsabligbini Forest Reserve in northern Ghana is one of the important protected areas in the savanna zone of Ghana. The reserve was created in 1956 to protect the headwaters of Moya River and its tributaries. To the best of our knowledge, however, there is no published information on the different species of plants found in the reserve that could assist those involved in the management of the reserve to develop appropriate management strategies for the conservation of the vegetation in the reserve.

The objective of the present study was therefore to (i) document the floristic composition, abundance and distribution pattern of woody plants in the Sinsabligbini Forest Reserve in northern Ghana and (ii) compare it with other areas in the Guinea Savanna Zone of West Africa particularly Ghana. It is hoped that this information could assist in the development of strategic management plans for the reserve.

MATERIALS AND METHODS

Study area

The study area at the Sinsabligbini Forest Reserve is situated about 20 km from Tamale, the Northern Regional Capital of Ghana. The reserve is located between latitude 09° 24 138 N and longitude 00° 38 377 W, and covers an area of 72.72 km^2. About 0.2 km^2 of the reserve area has been converted into a plantation of *Eucalytptus* sp., *Tectona grandis* L. and *Anogeissus leiocarpus* Guill & Perr. The natural vegetation in the reserve area is guinea savanna. The terrain is generally flat and the soil in most areas of the reserve is shallow with exposed laterite. In seasonally flooded areas of the reserve the soil is mainly made up of clay and silts.

The reserve area experiences one rainy season between May and October each year with a peak period in August and a dry season from November to March. The average annual rainfall and temperature are 1034.1 mm and 26.7° C, respectively. There are over 10 communities living around the reserve and the people are mostly from the Dagomba ethnic group. Most of the people living around the reserve are farmers.

Methods

The woody plants in the natural vegetation area of the reserve were studied using vegetation plots. With reference to Landsat EM 2000 satellite images and topographical maps, we located different habitat areas in the reserve and randomly demarcated circular vegetation plots of 10 m radius (ca. 314 m^2 size) in each of the habitat areas. In total, 15 vegetation plots were examined; at least three plots were demarcated for each different habitat area. All species of woody plants found rooted within each plot were identified and their individual plants counted.

The identification of the species of plants encountered was later confirmed using relevant literature (Arbonnier 2000; Hutchinson & Dalziel 1957–1972), and by comparison with already identified specimens at the Ghana Herbarium located at the Department of Botany, University of Ghana.

Data analysis

The individual-based rarefaction methodology described by Gotelli and Colwell (2001) was used to estimate the expected number of species for the construction of species accumulation curve with 95% confidence interval. The free statistical software Estimates version 8.0 (Gotelli 2006) was used for the species accumulation curve. The program was set to randomized samples with replacement and shuffle; the individual of plants among plots within species 1000 times.

The variance: mean ratio of individuals per unit area can be used as a measure of the degree of randomness or aggregation in populations or whole communities (Pilou 1977; Sokal & Rolf 1981). Chi-squared test was used to determine whether the pattern of distribution was significantly random or aggregated based on the variance: mean ratio calculated for each species (Lambshead & Hodda 1994; Rice & Lambshead 1994).

RESULTS

Floristic composition

In total, 2534 individuals of woody plants belonging to 62 species in 48 genera and 19 families were identified in the reserve. The individual-based species accumulation curve shows that the majority of woody plants in the reserve were sampled during the study as seen in the curve as it reaches the asymptote (Fig. 1). The list of species, their families and growth-forms are presented in Table 1. The majority (40.3%) of the species were big trees, followed by small trees (29.0%) and shrubs (27.4%). Two species namely, *Dalbergia afzeliana* G. Don. and *Opilia celtidifolia* Endl. ex Walp.were the only lianas identified. About 62.9% of the woody plant genera in the reserve consisted of only one species. Genera with two or more species were *Acacia* (3 species), *Annona* (2 species), *Bridelia* (2 species), *Combretum* (4 species), *Gardenia* (2 species), *Lannea* (2 species), *Strychnos* (2 species), *Terminalia* (3 species) and *Vitex* (2 species).

The most species rich family (29%) was Fabacaeae, followed by Combretaceae (14.5%), and Rubiaceae (11.3%). Other taxonomic families with many species were Verbenaceae (6.5%), Euphorbiaceae (6.5%), Anac-

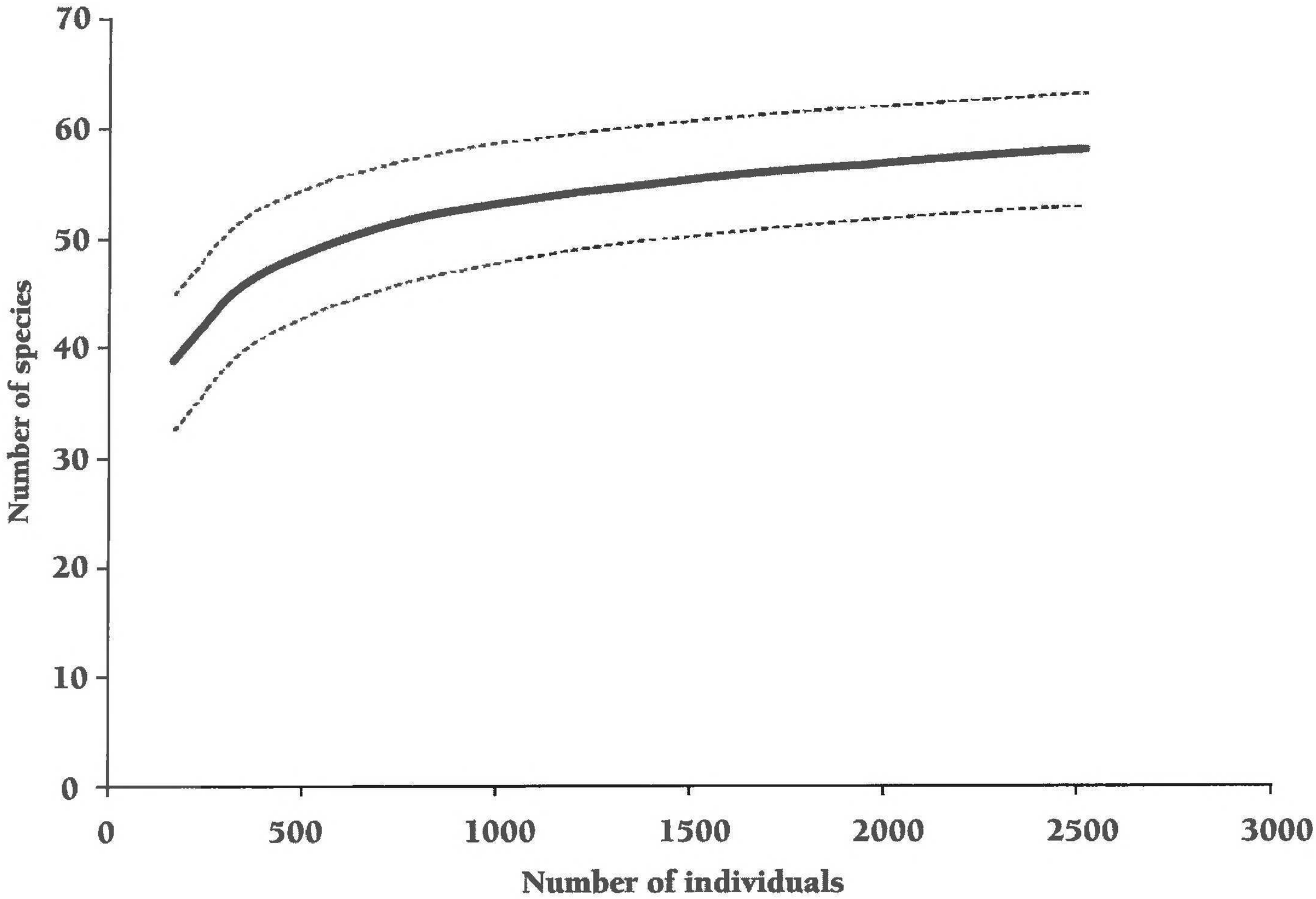

Fig. 1. Individual-based species accumulation curve for woody plants in Singsaglebini Forest Reserve in northern Ghana.

ardiaceae (4.8%) and Annonaceae (4.8%) in decreasing order of number of species (Table 2). Ten (52.6%) of the families, namely, Bignoniaceae (*Stereospermum kunthianum* Cham.), Bombacaceae (*Bombax costatum* Pellegr. & Vuillet), Celastraceae (*Maytenus senegalensis* (Lam.) Exell), Cornaraceae (*Rourea coccinea* (Schumach. & Thonn.) Hook.f., Moraceae (*Ficus* sp.), Opiliaceae (*Opilia celtidifolia* Endl. ex. Walp.), Polygalaceae (*Securidaca longepedunculata* Fresen.), Proteaceae (*Protea madiensis* Oliv.), Sapotaceae (*Vitellaria paradoxa* C.F. Gaertn.) and Tiliaceae (*Grewia venusta* Fresen.) were each represented by only one species indicated in brackets. The families with highest number of individuals were Fabaceae and Combretaceae. These families contributed about 68.7% of individuals to the woody flora in the reserve. Seven other families (Bombacaceae, Celastraceae, Moraceae, Opiliaceae, Polygalaceae, Proteaceae and Verbanaceae) contributed less than one percent of the total number of individuals per family. The families Moraceae and Polygalaceae were least abundant with each one represented by only one individual plant recorded in the reserve.

Abundance and distribution pattern

The six most abundant woody plants in the reserve were *Dichrostachys cinerea* (L.) Wight & Arn. (Fabaceae), *Pteleopsis suberosa* Engl. & Diels (Combretaceae), *Combretum collinum* Fresen. (Combretaceae), *Dalbergia afzeliana* G. Don. (Fabaceae), *Terminalia mollis* S.Vidal. (Combretaceae), and *Vitellaria paradoxa* C.F. Gaertn. (Sapotaceae) in decreasing order of abundance (Table 1). These species contributed about 57.3% of the total number of individual of plants identified. In contrast the least abundant species were *Bridelia micrantha* Baill., *Daniellia oliveri* (Rolfe) Hutch. & Dalziel, *Ficus* sp., *Gardenia aqualla* Stapf. & Hutch., *Parkia biglobosa* (Jacq.) R.Br.ex G. Don, *Securidaca longepedunculata* Fresen., and *Vitex chrysocarpa* Planch.Eight of the woody plants in the reserve were frequently encountered, i.e., in 50% or more of the plots studied. These species were *Combretum mollis* S. Vidal, *Crossopteryx febrifuga* Benth., *Vitellaria paradoxa* C.F. Gaertn., *Strychnos spinosa* Lam., *Annona senegalensis* Pers., *Grewia venusta* Fresen., *Combretum* sp., and *Pterocarpus erinaceus* Lam. It

Table 1. Species of woody plants, their families, growth-form, abundance, frequency of occurrence and distribution statistics in Singsaglebini Forest Reserve in northern Ghana.

Species	Family	Growth-form	Abundance	Frequency of occurrence	Distribution statistics (df =14)				
					Variance	Mean	χ^2	Probability	Pattern
Acacia dudgeoni Craib	Fabaceae	Small tree	2	3	0.27	0.13	28	0.014	Aggregated
Acacia gourmaensis A. Chev.	Fabaceae	Tree	24	2	9.10	1.67	76.40	0	Aggregated
Acacia hockii De Wild.	Fabaceae	Small tree	19	1	17.21	1.27	190.21	0	Aggregated
Acacia tortilis Hayne	Fabaceae	Small tree	40	5	35.24	2.67	185	0	Aggregated
Afzelia africana Sm.	Fabaceae	Tree	86	4	342.21	5.73	835.63	0	Aggregated
Annona glauca Schumach. & Thonn.	Annonaceae	Shrub	2	2	0.12	0.13	13	0.53	Random
Annona senegalensis Pers.	Annonaceae	Shrub	55	9	25.10	3.67	95.82	0	Aggregated
Anogessius leiocarpus Guill & Perr.	Combretaceae	Tree	77	7	95.41	5.13	260.21	0	Aggregated
Bombax costatum Pellegr. & Vuillet	Bombacaceae	Tree	4	2	0.64	0.27	33.5	0.0026	Aggregated
Bridelia ferruginea Benth.	Euphorbiaceae	Small tree	19	7	5.78	1.27	63.89	0	Aggregated
Bridelia micrantha Baill.	Euphorbiaceae	Small tree	1	1	0.067	0.067	14	0.45	Random
Burkea africana Hook.	Fabaceae	Small tree	24	4	13.40	1.60	117.25	0	Aggregated
Combretum collinum Fresen	Combretaceae	Small tree	179	4	98.07	11.93	115.05	0	Aggregated
Combretum molle R. Br. ex G. Don.	Combretaceae	Small tree	84	13	26.11	5.60	65.29	0	Aggregated
Combretum nigricans Leprieur ex Guill. & Perr	Combretaceae	Small tree	40	1	39.52	2.67	207.5	0	Aggregated
Combretum sp.	Combretaceae	Small tree	12	9	9.60	0.80	168	0	Aggregated
Crossopteryx febrifuga (Afzel. ex G. Don.) Benth.	Rubiaceae	Tree	56	11	19.50	3.73	73.11	0	Aggregated
Dalbergia afzeliana G. Don	Fabaceae	Tree	150	1	1500.0	10.00	2100	0	Aggregated
Daniellia oliveria (Rolfe) Hutch. & Dalz.	Fabaceae	Tree	1	1	0.067	0.067	14	0.45	Random
Detarium microcarpum Guill. & Perr.	Fabaceae	Tree	32	4	17.12	2.13	112.38	0	Aggregated
Dichrostchys cinerea (L.) Wright & Arn.	Fabaceae	Shrub	339	5	2625.69	22.60	1626.53	0	Aggregated
Entada africana Guill & Perr.	Fabaceae	Small tree	20	6	4.52	1.33	47.5	1.93E-05	Aggregated
Feretia apodanthera Del.	Rubiaceae	Shrub	10	2	5.38	0.67	113	0	Aggregated
Ficus sp	Moraceae	Tree	1	1	0.067	0.067	14	0.45	Random
Gardenia aqualla Stapf. & Hutch.	Rubiaceae	Shrub	1	1	0.067	0.067	14	0.45	Random
Gardenia ternifolia Schum. & Thonn.	Rubiaceae	Shrub	25	7	6.67	1.67	56	8.00E-07	Aggregated
Grewia venusta Fresen.	Tiliaceae	Small tree	41	9	12.35	2.73	63.27	1.00E-07	Aggregated
Hexabolus monopetalus Engl. & Diels.	Annonaceae	Shrub	34	3	26.35	2.27	162.76	0	Aggregated
Hoslundia opposita Vahl	Verbanaceae	Shrub	10	2	5.38	0.67	113	0	Aggregated
Hymenocardia acida Tul.	Euphorbiaceae	Tree	4	2	0.50	0.27	26	0.026	Random
Khaya senegalensis A. Juss.	Meliaceae	Tree	16	1	17.07	1.07	224	0	Aggregated

Species	Family	Growth-form	Abundance	Frequency of occurrence	Distribution statistics (df =14)				
					Variance	Mean	χ^2	Probability	Pattern
Lannea acida A. Rich	Anacardiaceae	Tree	12	3	2.89	0.80	50.5	6.50E-06	Aggregated
Lannea barteri Engl.	Anacardiaceae	Tree	7	5	0.55	0.47	16.57	0.28	Random
Lippia multiflora Moldenke	Verbanaceae	Shrub	2	1	0.27	0.13	28	0.014	Aggregated
Maytenus senegalensis (Lam.) Exell.	Celastraceae	Shrub	3	2	0.31	0.20	22	0.078	Random
Mitragyna inermis (Willd.) Kuntze	Rubiaceae	Tree	19	3	15.07	1.27	166.53	0	Aggregated
Nauclea latifolia Sm.	Rubiaceae	Shrub	15	1	5.14	1.00	72	0	Aggregated
Opilia celtidifolia Endl. ex. Walp.	Opiliaceae	Liana	4	1	1.07	0.27	56	8.00E-07	Aggregated
Papilionaceae	Fabaceae	Tree	35	2	60.24	2.33	361.43	0	Aggregated
Parkia biglobosa (Jacq.) R.Br. ex G.Don	Fabaceae	Tree	1	2	0.067	0.067	14	0.45	Random
Pavetta corymbosa F.N. Williams	Rubiaceae	Shrub	2	1	0.27	0.13	28	0.014	Aggregated
Pericopsis laxiflora (Benth. ex Baker) Meeuwen	Fabaceae	Tree	46	2	70.64	3.067	322.48	0	Aggregated
Piliostigma thonningii (Schumach.) Milne-Redh	Fabaceae	Shrub	13	3	4.41	0.87	71.2308	0	Aggregated
Prosopis africana Taub.	Fabaceae	Tree	3	2	0.31	0.20	22	0.078	Random
Protea madiensis Oliv.	Poteaceae	Shrub	19	2	12.07	1.27	133.37	0	Aggregated
Pseudocedrela kotschyi Harms	Meliaceae	Tree	33	7	15.17	2.20	96.55	0	Aggregated
Pteleopsis suberosa Engl. & Diels	Combretaceae	Small tree	298	5	1953.84	19.87	1376.87	0	Aggregated
Pterocarpus erinaceus Lam.	Fabaceae	Tree	40	8	14.67	2.67	77	0	Aggregated
Rourea coccinea (Schumach. & Thonn.) Hook.f.	Connaraceae	Shrub	116	5	166.92	7.73	302.19	0	Aggregated
Securidaca longependuculata Fresen.	Polygalaceae	Small tree	1	1	0.067	0.067	14	0.45	Random
Securinega virosa (Willd.) Baill.	Euphorbiaceae	Shrub	74	6	98.92	4.93	280.73	0	Aggregated
Stereospermum kunthianum Cham.	Bignoniaceae	Tree	29	5	18.50	1.93	133.93	0	Aggregated
Strychnos innocua Delile.	Loganiaceae	Small tree	7	1	3.27	0.47	98	0	Aggregated
Strychnos spinosa Lam.	Loganiaceae	Small tree	69	9	31.97	4.60	97.30	0	Aggregated
Terminalia avicenoides Guill. & Perr.	Combretaceae	Small tree	20	3	15.38	1.33	161.5	0	Aggregated
Terminalia macroptera Guill. & Perr.	Combretaceae	Tree	29	2	26.92	1.93	194.97	0	Aggregated
Terminalia mollis S.Vidal	Combretaceae	Tree	115	7	207.10	7.67	378.17	0	Aggregated
Trichilia emetica Vahl	Meliaceae	Tree	13	1	11.27	0.87	182	0	Aggregated
Vitellaria paradoxa C.F. Gaertn.	Sapotaceae	Tree	84	9	131.69	5.60	329.21	0	Aggregated
Vitex chrysocarpa Planch.	Verbanaceae	Shrub	1	1	0.067	0.067	14	0.45	Random
Vitex doniana Sweet	Verbanaceae	Shrub	6	1	2.40	0.40	84	0	Aggregated
Xerroderis stuhlamanii (Taub.) Mendonca & E.P. Sousa	Fabaceae	Tree	10	3	2.52	0.67	53	2.60E-06	Aggregated

TABLE 2. Families of woody plants, their species richness and abundance in the Singsaglebini Forest Reserve in northern Ghana.

Family	Species richness (number of species)	Relative species richness	Abundance (number of individuals)	Relative abundance
Anacardiaceae	3	4.8	32	1.3
Annonaceae	3	4.8	91	3.6
Bignoniaceae	1	1.6	29	1.1
Bombacaceae	1	1.6	4	0.16
Celastraceae	1	1.6	3	0.12
Combretaceae	9	14.5	854	33.7
Connaraceae	1	1.6	116	4.6
Euphorbiaceae	4	6.5	98	3.9
Fabaceae	18	29.0	886	35.0
Loganiaceae	2	3.2	76	3.0
Meliaceae	2	3.2	49	1.9
Moraceae	1	1.6	1	0.04
Opiliaceae	1	1.6	4	0.16
Polygalaceae	1	1.6	1	0.04
Poteaceae	1	1.6	19	0.75
Rubiaceae	7	11.3	127	5.0
Sapotaceae	1	1.6	84	3.3
Tiliaceae	1	1.6	41	1.6
Verbanaceae	4	6.5	19	0.75

thus follows that the most abundant woody plants in the reserve were not necessarily the most frequently encountered plants.

The result of the analysis of the general pattern of distribution of the woody plant community in the reserve shows that the species were highly aggregated (χ^2 =12465.8, df = 930, P = 0). The distribution of the individual woody plant species was highly discordant with respect to each other (χ^2 = 11746.5, df = 916, P= 0) whiles individual species were found to be highly aggregated in the plots (χ^2 = 719.3, df =14, P = 0). The majority (80.6%) of the individual woody plant species were found to be aggregated in their pattern of distribution in the reserve (Table 1). In contrast, twelve of the species, namely, *Annona glauca* Schumach. & Thonn., *Bridellia micrantha* (Hochst.) Baill. *Daniellia oliveria*, *Ficus* sp., *Gardenia aqualla*, *Maytenus senegalensis* (Lam.) Exell., *Hymenocardia acida* Tul., *Lannea barteri* Engl., *Parkia biglobosa*, *Prosopis africana* Taub., *Securidaca longependuculata*, and *Vitex chrysocarpa* showed some degree of randomness in the pattern of distribution in the reserve.

DISCUSSION

Most of the species of plants identified in the Sinsabligbini Forest Reserve in northern Ghana are species that have been reported in other guinea savanna areas elsewhere in Ghana (Lawson et al. 1969; Brookman-Amissah et al. 1980; Oteng-Yeboah 1996; Asase & Oteng-Yeboah 2007). However, a few of the species such as *Rourea coccinea* (Schumach &. Thonn.) Hook.f., *Dalbergia africana*, and *Hoslundia opposita* Vahl that were identified in the reserve have not been reported in other areas in the Guinea Savanna Zone of Ghana based on survey of the available literature. Similarly, some of the common woody plant species such as *Balanities aegyptiaca* Sands. and *Ximenia americana* L. that have been reported in other areas of the Guinea Savanna Zone of Ghana were not identified in the reserve. This finding has confirmed that the floristic composition of the savanna is immensely variable even over relatively homogeneous areas (Hopkins 1979; Lawson 1985).

The high species richness and abundance of taxonomic families such as Fabaceae, Combretaceae, Rubiaceae, and Anacardiaceae in the guinea savanna has been noted elsewhere (Hopkins 1979; Asase & Oteng-Yeboah 2007). In a study of three traditional groves in northern Ghana, Oteng-Yeboah (1996) also

reported on the predominance of members of the Fabaceae (Caesalpinaceae, Papilionaceae, and Mimosaceae), Combretaceae, Rubiaceae in the different groves which report is similar to the results of this study. It is also interesting to note that even though some of the families such as Verbenaceae and Anacardiaceae were found to have several species, their individual plant representation were very low. On the other hand, there were more individual members of some of the families with lower species numbers such as Connaraceae and Sapotaceae. It thus follows that not all the families with many species are abundant in the reserve. It is important to note that some of the important guinea savanna trees such as *Afzelia africana* Sm., *Daniellia oliveria*, and *Parkia biglobosa* (Hopkins 1979; Lawson 1985) were not abundant in the reserve.

In a study of the pattern of distribution of some woody plants in the Olokemeji Forest Reserve in Nigeria, Greig-Smith (1991) noted that patchiness could be explained as a response to factors such as soil differences, pattern of previous farming, intensity of burning from wild fires and at the smallest scale interference between individual plants possibly due to competition for water. We found evidence of annual wild bush fires and farming activities in the reserve and these factors might also explain the pattern of distribution of the woody plants in the reserve. As yet there are no reports on the patterns of distribution of savanna plants in Ghana and so no comparisons could be made.

To conclude, the present study is the first publication on the species of plants found in the Sinsabligbini Forest Reserve in northern Ghana. The study has shown that the characteristics of the vegetation in the reserve were generally similar to that of other guinea savanna areas. It has also shown that the floristic composition and abundance of species in different areas of the Guinea Savanna Zone is very variable. Thus there is a case for the study of the diversity of plants found in the different areas of the Guinea Savanna Zone of Ghana in order to support the conservation of savanna botanical resources especially for specific areas of the Guinea Savanna Zone in Ghana.

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REFERENCES

Anonymous. 2002. National biodiversity strategy for Ghana. Ministry of Environment and Science.

Arbonnier, M. 2000. Arbres, arbustes et lianes des zones sèches d'Afrique de l'Ouest. CIRAD, MNHN, UICN.

Asase, A. and A.A. Oteng-Yeboah. 2007. Assessment of plant biodiversity in the Wechiau Community Hippopotamus Sanctuary in Ghana. J. Bot. Res. Inst. Texas 1(1): 549–556.

Baker, H.G. 1962.The ecological study of vegetation in Ghana. In: J.B. Willis, ed. Agriculture and land use in Ghana. Oxford. Pp 151–159.

Brookman-Amissah, J., J.B. Hall, M.D. Swaine, and J.Y. Attakorah. 1980. A re-assessment of a fire protection experiment in north-eastern Ghana savanna. J. Applied Ecol. 17:85–99.

Gotelli, N.J. 2005. EstimateS statistical estimation of species richness and shared species from samples. http://viceroy.eeb.uconn.edu/EstimateS pages/EstimateS.flx.

Gotelli, N.J. and R.K. Colwell. 2001.Quantifying biodiversity: procedures and pitfalls in the measurements of species richness. Ecol. Letters 4:379–391.

Greig-Smith, P. 1991. Pattern in a derived savanna in Nigeria. J. Trop. Ecol. 7:491–502.

Hopkins, B. 1979. Forest and savanna. Heinemann Educational Books Ltd 2nd Edition.

Houssain, M. and J.B. Hall. 1969. The tree of Mole National Park, Damongo, Ghana. Revised by Jongking, C.C.H., 2nd edition. University of Ghana.

Hutchinson, J. and J.M. Dalziel. 1957–1972. Flora of West Tropical Africa. Crown overseas agent, London.

Lambshead, P.J.D. and M. Hodda. 1994. The impact of disturbance on measurements of variability in marine nematode populations. Vie & Milieu 44:21–27.

Lawson, G.W., J. Jenik, and K.O. Armstrong-Mensah.1969. A study of a vegetation catena in guinea savanna at Mole Game Reserve (Ghana). J. Ecol. 56:505–522.

Oteng-Yeboah, A.A. 1996. Biodiversity in three traditional grooves in the Guinea Savanna, Ghana. In: L.J.G. van der Maesen et al. eds. The biodiversity of African plants. Kluwer Academic Publishers, Dordrecht, London. Pp. 188–197.

Pielou, E.C. 1977. Mathematical ecology. 2nd edition. John Wiley and Sons, New York.

Ramsay, J. and R. Rose Innes. 1963. Some quantitative observations on the effects of fire on the Guinea savanna vegetation of northern Ghana over a period of eleven years. Sols Africains 8:41–85.

Rice, A. L. and P.J.D. Lambshead. 1994. Patch dynamics in the deep-sea benthos: the role of a heterogeneous supply of organic matter. In: P.S. Giller, A.G. Hildrew, and D.G. Raffaelli, eds. Aquatic ecology: scale, pattern and process. 34th Symposium of the British Ecological Society. Blackwell Scientific Publications. Oxford. Pp.469–499.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry.2nd edition. W.H. Freeman and Company, San Francisco.

Taylor, C.J. 1952. The vegetation zones of the Gold Coast. Bull. Forest Dept. Gold Coast 4:1–12.

Vigne, C. 1936. Forests of the Northern Territories of the Gold Coast. Empire Forest J. 15:210–213.